Lloyd

A few notes on electric railways

Engineers' Society of Western Pennsylvania.

This Society does not hold itself responsible for the opinions of its members.

Tuesday, February 21st, 1888.

Society met at 8 o'clock, P. M., President Dempster in the chair.

By invitation, the National Electric Light Association, now holding a convention in our city, joined with us in this evening's meeting.

One hundred members and visitors were present.

The minutes of the January 7th meeting were read and approved.

Messrs. Isaac Winn, H. White and E. D. Estrada were elected members.

The subject of the paper for the evening was "Electric Railroads," by Mr. R. McA. Lloyd, the engineer of the electric railroad now in process of construction on the "South Side" of our city. The introduction to the subject was made by Prof. A. E. Frost, Treasurer of the Society, who, in language plain, clear and forcible, explained the technicalities and terms in such a way as to make even a tyro understand their meaning and application. He illustrated his definitions of terms, as a teacher to his class, with as much force and freedom as if he were in the schoolroom and the audience his pupils, whilst they, in return, showed their appreciation by close attention to what he said, and many of them were delighted with the lesson learned.

The reading of the paper by Mr. R. McA. Lloyd followed, viz.:

A Few Notes on Electric Railways.

An electric railway always consists of three parts:

First. A generating station where the electricity is made.

Second. A number of cars propelled on a track by electric motors.

Third. A medium through which the current is transmitted; which medium may be either metallic conductors—overhead, surface or underground—or storage batteries.

The field covered by each one of these headings has unfolded so many times in the last few years that whereas, three or four years ago, you might have been told in a half hour or so all there was to know about electric railroads, at the present time I can only attempt to bring to your notice, in a desultory way, a few of their most conspicuous features.

Well, the generating station is a good place to start from. We are all familiar with the appearance of a dynamo, and Prof. Frost has just told us the principle of its action, but without going into technicalities I might say another word about the dynamo.

The magnets of a dynamo literally resist every stroke of the engine, every pound of steam pressure behind it, and as no power can ever be lost, energy expended in one way must turn up in some other form. The resistance which the dynamo magnets offer to the engine is converted into an electric current, and the output of the dynamo will be exactly equal to the horse-power expended in driving its armature, minus a small proportion used to excite the field magnets and a smaller proportion lost in friction of bearings and heat.

The ordinary efficiency of a dynamo is 85 or 90 per cent., being far higher than that of a steam engine; the efficiency of the latter rarely rising above 15 per cent.; that is to say, a dynamo loses but 10 per cent. in the conversion of mechanical energy into electrical energy, while a steam engine loses 85 per cent. in converting the energy of heat into mechanical energy.

It is a little ahead of my story, but here let me say that motors, or receivers as we call them in distinction from generators, or dynamos have the same efficiency as the latter. Both are built on

the same general principles, and the sources of waste are the same in each.

The generating consists of a steam plant, engine, boilers, etc., and one or more dynamos, besides a safety cut-out to protect the dynamos from lightning and overloading.

It is not necessary to enumerate the smaller apparatus, but it is important to state that no power station is complete without a smaller space set apart for a repair shop, where a lathe and a handy man with a few tools can save money for the company.

There are two simple methods of distributing electric energy, both of which can be used for electric railways. They are, either by a constant current of varying intensity, or by a varying current of constant intensity. The former is the one used for arc lighting and the latter for incandescent, and is also the easier, safer, and more commonly used for the transmission of power.

Most of us prefer the constant tension method, but there are various opinions as to the best standard of tension, and for my part I should say that a good deal depends on the requirements and circumstances. I recommend (not only as being the system of the company which I represent, but from considerable experience and vivid recollections of personal contact with the subtile fluid) a tension as low as possible. In respect to pressure, electricity is analogous to gas or any fluid. You might sit on the opening of an eight inch low pressure gas main, and thereby stop the flow, but a seat on a two and half inch high pressure pipe would be a difficult one to maintain.

Any E. M. F. or tension above 300 volts is dangerous to human life and becomes troublesome in the matter of leakage. Greater care is necessary all around. I do believe, however, that high tension currents are advisable on a road of considerable length, say in cases where the wires extend more than five miles from the power station. Whatever may be the constant of tension, the dynamos can be built to regulate themselves accurately, and—what is the great beauty of electric transmission of power—produce just as much electricity as the moment demands at the motors on the road. The dynamos respond with a promptness that is simply wonderful to every pull of the motors. But now we must hurry on to the motors. They are running independently of each other

on the road. One, two, or a hundred can all get their current from the same conductors and run in different directions with the same current; and, so long as the capacity of the generating station is not exceeded, will have no influence over each other.

The best place for the motor is under the car and directly supported by the axles which it drives, though some builders with good reason put it on the front platform, which requires a special construction of car and trucks, and an unsymmetrical suspension of the wheels to compensate for the weight of the motor in front. For very heavy service it is often convenient to have the motor in a separate car. If the motor is situated on a car platform the motion of the armature is communicated to the car wheels by sprocket chains or belts.

When the motor is placed under the centre of the car, tooth or worm gearing is used to drive the car axles. It is quite common to equip a street car with two motors, one on each car axle, so that if one motor should be disabled its mate could bring the car home; on the other hand, it is very rarely that a well cared for motor becomes so worthless in one trip that it can't pull itself home; and if such a case should occur, the next car that comes along can push the disabled one ahead of it. Motors can be built for any desired speed and for the development of any desired power. As adapted to tramway service, they are generally arranged so that the speed may be varied by the driver of the car. The weight of motor with gearing and all other apparatus included in the electrical equipment of a tramcar, capable of doing the work of a first class team on any of the Pittsburgh railways, would be 1,500 pounds.

The nominal capacity of such a motor would be seven or eight horse-power, with the ability to work up to fifteen horse-power when necessary, as when starting a heavily loaded car on a seven per cent. gradient.

It has been demonstrated by the use a of dynamometer between the car and whiffletree, that a pair of horses often exerts this enormous strain under like conditions.

The current is generally carried from the generators to the motors by overhead conductors, that being the cheapest method, though there is no reason why underground conductors in conduits

similar to those of cable railways, cannot be used with equal satisfaction. As for surface conductors, meaning a third rail insulated from the ground, they are not permissible in any common thoroughfare, and so will not demand our attention this evening.

The overhead conductor may be supported in many ways, either at the side of a street or in the centre, and usually at a height of 20 feet. It consists of one or two hard drawn bare copper wires, stretched more or less tight and suspended in such a way that its supports do not obstruct the passage of a rolling trolley. The trolley may consist of one, two, or more rolling sheaves, combined with a view of traveling easily on the wires without falling off. The car tows its trolley along by a flexible cable, which also carries the current down to the motor.

The thickness of the overhead conductor is based upon the amount of current which it is required to carry, and for the transmission of the same amount of power depends on the electromotive force or tension. Just as a small pipe may transport as much gas or water at a high pressure as a large pipe can at a low pressure, so a small wire can carry as much power at a high tension as a large wire at a low tension. It is, therefore, evident that the high tension presents a saving in first cost of copper wire. The cost of the wire is, however, such a comparatively small item in the equipment of an electric railway, that it is overbalanced by the considerations of safety and insulation; and if we would have a road which could be guaranteed free from danger in case of accidental contact with the current, and at the same time not too wasteful of copper, we must strike a medium which may be worked out from two standpoints. We may either adopt a tension which will be as high as possible without being dangerous, or as low as possible without requiring an enormously large conductor.

In parallel systems of distribution which I have described, it is only necessary to insulate one side of the circuit, just as in water power it is only necessary to save the water in the dam. After the water has gone through the wheel to the pool below, it is useless so far as any influence on the same wheel is concerned.

If one side of an electric circuit is insulated so as to dam it up, as it were, we do not care what becomes of the current when it has gone through the motors to the other side; it is, therefore, quite

common to use the rails for the return to the dynamos—corresponding to the pool below the mill dam.

The current then goes from the insulated conductor through the motor, and by way of the wheels to the rails and back to the dynamos. When a wire is used for the return instead of the rails it serves in the same capacity, and the return current has no power to lose by bad insulation. Where the rails are likely to be continually buried in dust, or other dirt, it is so difficult for the wheels to maintain a metallic contact with them, that the return by an overhead wire is preferable, and there must be either a single trolley on each wire, or a double trolley bearing on the two wires at once, with the wheels on one side insulated from the wheels on the other side, and communicating with the car by a double cable through which the intense current proceeds to the motor and the spent current returns from it.

An electric railway using line conductors is a unit. The generating plant, the conductors and the motors are inseparable. In order to keep the motors running, the conductors must be kept in order, and the dynamos must generate continually; but where storage batteries are used the case is different. I need not describe to you a storage battery, beyond telling you that enough of it to run a street car four hours under ordinary conditions, weighs at least 2,600 pounds, and occupies the space under the seats on both sides of the car. Every car possessed of a motor and storage battery is independent, except when the battery gets short circuited and the stored energy runs out, in which event it has to be hauled home by animal power.

There is, doubtless, a large field of usefulness for storage batteries, and the subject would be interesting to dwell on, but at the present time they are too costly, and not far enough perfect for every day wear and tear on a city street. I do not make this statement from any personal prejudice, but as the opinion of a great many people of wide experience in electric railways. My own company is prepared to equip roads with storage batteries when wanted, but we do not recommend them.

I may say also of storage batteries, that their use entails a further loss of 20 per cent. in the transmission of power from dynamos to motors, and, therefore, necessitates a power plant of

proportionally greater capacity. The batteries, consisting of cells containing lead plates and acidulated water, are charged at the power station, or car shed, by the dynamo current, and fresh sets slipped under the car seats about every four hours. When a more lasting material has been found to take the place of lead in storage batteries we shall look for better results in that quarter. A car supplied with current by an overhead or underground conductor has an unlimited source of power to draw from, but one dependent upon storage batteries may, by a heavy pull, run out of power and have to bear the mortification of a homeward trip with a mule team.

Having briefly touched upon the three elements of an electric railway—the generating station, the motors, and the medium of transmission— I shall now glance at some of the minor features.

Electric brakes are a common and simple institution, and almost anybody can devise a very practicable one; but the old hand brake is after all the most reliable for street car service. There are, however, several ways of controlling an electric car on down grades without the use of brake shoes. On the motors of the St. Clair road, on the South Side, we have provided an arrangement of current switches, by which the heaviest load may be safely and smoothly carried down a hill, the equal of which has never before been attempted by any mechanical tractor. We take a little current from our line wires—about $1\frac{1}{2}$ horse-power from the dynamos to magnetize the motor, or, more accurately speaking, to excite the field magnets; then we allow the motor to act as a generator, converting the force of gravity which pulls it down hill into electricity. Perhaps I have not clearly explained that generators and motors are practically the same in principle, so that a generator may be used as a motor, or a motor as a generator.

Well, the same gearing by which the rotating armature of the motor drives the car up hill, going down hill transmits the motion of the car axles back to the armature, and as the armature revolves about ten times as fast as the car wheels, it is not necessary to run down hill very fast to obtain a high speed for the armature, and as the current generated by the armature is proportional to its speed of rotation in a constant magnetic field, and as the work of driving the armature increases with this current, it stands to reason

that the faster the train runs the greater power resistance it will offer to its own descent.

This amount of current or retarding power can also be increased by diminishing the resistance of the armature circuit, for which purpose we provide a variable resistance to be operated by the driver with a small turning handle.

Cars may descend hills with ease using this device, but I do not consider such methods necessary except on extraordinary grades, and recommend the omission from an electric car of everything that is not absolutely necessary, for complications of wires need much careful watching.

Electric cars should be lit by electric lights, but as for electric bells, electric heaters, electric indicators and fare boxes and other electric fixings, they are nuisances which do well for advertising without adding to the serviceability of a hard working road.

I have been asked a hundred times whether ice and snow interfere with the operation of electric tramways.

Ice and snow interfere with electric tramways just as much as with horse roads. Any track which a horse car can safely go down on, is good enough for an electric car to go down or up on; for if the wheels of the horse car can get enough hold to go down on it without coasting, the wheels of the electric car will take sufficient hold of the same track to climb up it. In short, salt and sand keep an electric road running in winter as well as they do a horse road, with the advantage that there are no horses' feet to be ruined by salt.

The advantages of electricity over horses are many. Speed, perfect control, easy stopping and starting, and economy. I won't bother you with estimates, but from the experience of the roads with which I have been connected, I can assure you that street cars can be run by electricity for less than one-half the expense of horses, and at the same time give the public better service, and in consequence reap a greater reward. Besides this, the ground required by an electric railway plant is small to that of a horse stable, to say nothing of the difference in the character of the employee. Last, I may remind you that electricity never gets the pink eye.

A more formidable rival of electricity is the cable. It is a

good thing, and claims, in common with the former, a great many of the advantages which I have just enumerated, but in cost the cable is away ahead of us.

Electric railways have so far been built too economically, but I am very moderate in statement when I say that an electric tramway can be built in any street in your city for $25,000 per mile, which will give as much satisfaction as the cable at $100,000, and that the cost of operating will be less.

However, as I have neither been invited to run down cables nor run up electricity, I shall not produce all the evidence which would surely convince you that electricity is the ideal power for street railway purposes, and that however ludicrous some of the experimenting has been, it is to-day as reliable as the mule or cable. Of course there are systems on the market which are no credit to the mighty force itself, but there are several companies that after years of discouraging work have brought their hopes to commercial success.

After which Dr. Moses, of New York, said:

The question of electric motors is one that is now so full of interest that I can be prompted to say something about them. I may say something that may be novel, as I have had opportunity of seeing quite recently abroad the development of electric motors there, and of hearing some expressions of opinion as to their probable future for use where other sources of power are now employed.

I was recently in London, and visited a gentleman who is connected with the Metropolitan Underground Railway. He had been looking into the question of motors, as also other stockholders, some of whom had come over to this country for the purpose of studying the matter. The Duke of Sutherland, who is, perhaps, the largest stockholder of the railroad, has given a great deal of personal study, as well as have his engineers, and a contract has been given out recently to Dr. Siemens (Siemens Brothers), of London, for the purpose of putting in a considerable section of electric railway in the Underground Railway of London.

I do not think I could, by any further expression of my own opinion, give you a greater idea of what importance electrical

motors have assumed, than when I tell you that the Metropolitan Underground Railway is one system and the only system of rapid travel in London. There are many omnibus lines, there are some horse car lines, but the only artery for rapid transportation in London is the underground railway.

The disadvantages of steam have become so apparent there that they have made up their minds to abandon it at the first opportunity, which will be the presentation to them of a successful system of electrical transportation.

It is true the conditions there are all favorable. You have an underground road protected from the weather, and no snow or ice which are found so objectionable to horse cars. You have no rain to fill up your conduits; no conductors; you have no teams crossing the road. Short circuit cars of course doubles them up. You have no persons interfering with the line; no small boy down there; and altogether the conditions are very favorable.

Again, on the other hand, the most favorable recommendation to the introduction is the fact that the atmosphere is absolutely intolerable. The foggy condition of London is such that when a puff of smoke gets down there it stays, and there is no way of getting it out, and the result is a most intolerable condition of affairs. I always preferred to go by cab to taking the underground road.

Now they have investigated the system, and I was called upon by Dr. Hopkinson to look into the question for them, and one of the most important systems of electric distribution now in use in America, very successfully, was under consideration by them; they are very willing to give them a trial. I was told by Dr. Siemens himself, that he was perfectly willing to undertake and introduce this American system in place of his own, provided certain arrangements were made.

In regard to the introduction of electric motors in Paris, I will say this, that there is now before the Municipal Council of Paris a proposition on the part of some cable roads, in successful operation in New York and on certain English railways, to put a complete line around Paris between the fortifications and between the tramways, as they are called, but this question, owing to legislative and governmental disturbance, has been cast aside for

the time being. There is, however, under advisement, a system of electrical transportation it is proposed to introduce in France, which has some very interesting features connected with it.

This system has certain very great advantages. I mention them to you as I believe they are novel. The cars are run on high tension, the current in multiple arcs, and they are not interfered with by the potential on the line, because feeders are sent out at certain very short intervals for the purpose of supplying the current, and in that way keep up the potential. It is necessary that the potential should always be uniform, as you know, and although, as has been said, quite a large number of motors can be run on the same line, it is only under certain favorable conditions, because they are like incandescent lamps, strong in multiple arcs along a single line.

There is a fall of potential due to the resistance of the wire. This fall is relatively great, and it has been found necessary to send out feeders. Now it is very necessary that you should avoid this fall of potential, hence the sending out of these feeders. One trouble had to be looked to, however, and that was the small boy. I was told by Mr. Payne, engineer of the Brooklyn bridge, that at first it was impossible to keep the conduits clean, and that they gathered up all sorts of rubbish that could possibly be imagined.

The genius of the inventor has, however, circumvented him, by arranging that when receiving the current the car covers the vulnerable point. I do not know but that there will be found some Achilles heel in it where the small boy will finally get in his work, but as at present devised, it is only when the car covers a certain length of rail that it is possible for the current to operate in the motor.

With this exception, the overhead arrangement is preferable as being safer, though we have still seen the cats and kites of the small boy suspended from the poles.

This is the arrangement proposed to be introduced in Paris. The cable people are confident of their scheme, but so are the electricians.

Society then adjourned for social intercourse with the visitors.

S. M. WICKERSHAM,
Secretary.